Fig. 2. Piece of the epiblast; the cells and nuclei stained with carmine. Magnified about 370 diameters.

Fig. 3. Piece of the hypoblast; similarly prepared. Magnified 370 diameters.

Fig. 4. Section across the germinal area of the developing ovum, stained with logwood. Magnified 200 diameters.

z.p. zona pellucida.
e.p. epiblast.
h.p. hypoblast.
m.l. Membrana limitans hypoblastica.

VI. "Preliminary Report to the Hydrographer of the Admiralty on some of the Results of the Cruise of H.M.S. 'Challenger' between Hawaii and Valparaiso." By Prof. WYVILLE THOMSON, F.R.S., Director of the Civilian Staff on board. Received February 26, 1876.

[This Report will appear in a subsequent Number of Proceedings.]

March 30, 1876.

Dr. J. DALTON HOOKER, C.B., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "An Experiment on Electro-Magnetic Rotation." By W. SPOTTISWOODE, M.A., Treas. and V.P.R.S. Received February 24, 1876.

The phenomena of the rotation of movable conductors, carrying currents, about lines of magnetic force are well known. One form of experiment, commonly called the rotating spark, presents, beside the actual rotation, some peculiar features which do not appear to have been noticed in detail. The instrumental arrangements consist of a partially exhausted chamber with a platinum point for one terminal, a ring for the other, and the intervening air or other gas for the movable conductor. The chamber is made in the form of a double cylinder, so that a magnet inserted through the ring may reach nearly to the point. The discharge then passes between the point and the ring, and revolves about the magnet according to Ampère's law.

But beside the rotation, and even when, through weakening of the magnet, rotation does not actually take place, the spark, when carefully observed, is seen to assume a spiral form; and the spiral is right-handed or left-handed according to both the direction of the current and the mag-

netic polarity. This effect is particularly noticeable if the magnetic pole be inserted only a short distance beyond the ring. The discharge is then seen to spread itself out sheetwise on the ring in the direction in which rotation would take place. The edge of the sheet is in the form of a helix.

The object of the following observations is to bring out the character of this phenomenon by making it a principal instead of a secondary feature of the experiment.

The arrangement here described consisted in using the poles of an electromagnet as the terminals of a discharge from an induction-coil, and in observing the effect on the form of the discharge caused by exciting the electromagnet. For this purpose the movable poles were insulated from the main body of the magnet by interposing a sheet of ebonite thick enough to prevent the passage of the discharge, but not thicker, in order as little as possible to diminish the strength of the magnetic poles. The discharge was then effected either in the open air or in a closed chamber. The latter was constructed of a short cylinder of glass, say 3 inches in length and 2 in diameter, having conical ends pointed inwards, so as to receive the poles of the magnet. The chamber was also furnished with a pipe and stopcock for the purposes of exhaustion.

The discharge from an induction-coil taken in air or other gas at atmospheric pressure consists, as is well known, primarily of the spark proper or bright line, irregular in form and instantaneous in duration. But beside this, when the primary wire is thick and the battery-current strong, the spark is enveloped in a bright cloud, or rather flame, which is capable of being thrown on one side, although not entirely detached from the spark, by a current of air. This, when examined in a revolving mirror, is found to be subsequent in time to the spark proper, and may be considered to be due to the gas in the neighbourhood of the spark becoming sufficiently heated to conduct part of the discharge, and to the consequent combustion of any extraneous matter floating in the medium. Such a view is supported by the fact that the colour of this flame depends partly upon the nature of the gas in which the discharge takes place, and partly upon that of any volatilizable matter which may be introduced near the poles.

The exciting of the magnet produces upon the spark proper no appreciable effect; but as soon as the flame is submitted to its action it is spread out into a sheet, which arranges itself in a helicoid right-handed or left-handed according to the direction of the current and of the magnetic polarity in obedience to Ampère's law.

Effects substantially the same are produced whether the discharge be taken in gas at atmospheric or at a less pressure. But in the former case the helix has a lower, in the latter a steeper gradient; that is to say, in the former case it presents a greater, in the latter a less number of turns for a given interval between the poles.

But for producing the best effects, both of the rotating spark and also of the spirals, there is a limit beyond which the exhaustion should not be carried. At a pressure low enough to produce stratification, or even short of it, the whole chamber is filled with the discharge, and all traces of rotation and of spirals are obliterated. The stage best suited to the purpose is that in which the discharge has thickened in diameter, and where the spark proper has been replaced by a suffused light of the thickness, say, of a quill. If the negative terminal be a surface (say the naked surface of the soft iron pole of the electromagnet) instead of a point, the sheet does not become contracted at the negative end, but remains spread out and cuts the iron pole in a line radiating from the point.

Various gases were tried—atmospheric air, carbonic acid, ether, chloroform, coal-gas, hydrogen. Of these the first two succeeded best. With air the illumination of the flame-sheet was rather greater; but with carbonic acid greater steadiness of position was obtained. With both ether and chloroform occasional flashes, brilliantly illuminated, were seen; but some chemical action appeared to take place militating against the steady development of the flame-sheet. With coal-gas there was an inconvenient deposit of carbon upon the sides of the chamber. With hydrogen the cloud was not sufficiently developed.

The success which attended the experiment with air may possibly be partly due, as suggested above, to the combustion of the extraneous matter floating therein; and in fact the brilliancy and extent of the sheet may be increased by attaching a piece of metallic sodium to the negative terminal, or by causing a stream of any of the chlorides in powder, *e. g.* of strontium, lithium, &c., to flow across the field of action.

When a piece of sodium (or better still of soda) is attached to one of the terminals, two effects may be noticed. When that terminal is negative the whole of the flame is bright yellow, showing that the sodium is not only detached but even carried across the field and deposited on the positive terminal. When, however, the terminal to which the sodium is attached is positive, it is found that the flame, when observed through a red glass, appears yellow to a certain distance from that terminal, but red beyond, and also that the pitch of the helix is less near the positive than near the negative terminal. These effects may be attributed to the presence of metallic vapour evolved by the heat at the positive terminal, but not carried across the field as when the terminal in question is negative.

The following explanation of the phenomenon is due to Prof. Stokes, from whose correspondence it is substantially taken. The mathematical solution, although only roughly approximate, is perhaps still quite sufficient to give the general character of the experimental results.

The magnetic field will be supposed uniform, and the lines of force parallel straight lines from pole to pole. The path of the current when undisturbed is also a straight line from pole to pole. In such a condition of things, every thing being symmetrical, no rotation would take place.

But if through any local circumstance, as in the experiment in air, or through heating of the chamber as in the exhausted tube, or otherwise, the path of the current be distorted and displaced, then each element will be subject to the action of two forces. To estimate these, let ds be an element of the path, with rectangular components dx, dy, dz, C the strength of the current, and R the magnetic force with components X, Y, Z, which in the first instance will be treated generally. Then one force will be that tending to impel the current in the direction of the axes respectively, and may be expressed by

$$C(Ydz-Zdy):ds, \quad C(Zdx-Xdz):ds, \quad C(Xdy-Ydx):ds.$$

Besides this, there will be the tendency of the current to follow the shortest path so as to diminish the resistance. Representing this as a tension τ, the components at one end of ds will be

$$-\tau dx:ds, \; -\tau dy:ds, \; -\tau dz:ds,$$

and those at the other

$$(\tau dx:ds)+d(\tau dx:ds) \;\ldots,$$

the algebraical sums of which are

$$d(\tau dx:ds), \; d(\tau dy:ds), \; d(\tau dz:ds),$$

and the equations of equilibrium then become

$$C(Ydz-Zdy)+d(\tau dx:ds)=0, \quad \ldots \quad (1)$$
$$C(Zdx-Xdz)+d(\tau dy:ds)=0, \quad \ldots \quad (2)$$
$$C(Xdy-Ydx)+d(\tau dz:ds)=0; \quad \ldots \quad (3)$$

taking s as the independent variable and multiplying by $dx:ds$, $dy:ds$, $dz:ds$ respectively, and adding, we obtain $d\tau=0$, or $\tau=$constant. Again, multiplying by X, Y, Z and adding we obtain

$$Xd^2x:ds^2+Yd^2y:ds^2+Zd^2z:ds^2=0, \quad \ldots \quad (4)$$

which expresses that the absolute normal (or normal in the osculating plane) is perpendicular to the resultant magnetic force.

In the case of a uniform tint, X, Y, Z will be constant. Integrating (4) and putting i for the angle between the tangent and the lines of magnetic force, we find

$$Xdx+Ydy+Zdz=Rds\cos i,$$

so that the tangent line is inclined at a constant angle to the line joining the poles.

Again, the following combinations, (2) $dz-$(3)$dy=0$, (3) $dx-$(1)$dz=0$, (1) $dy-$(2)$dx=0$ give

$$Cdx(Xdx+\ldots)-CXds^2+\tau\left(\frac{dz}{ds}\frac{d^2y}{ds^2}-\frac{dy}{ds}\frac{d^2z}{ds^2}\right)ds^2=0, \text{ \&c.},$$

or

$$C(R\cos i\, dx-Xds)+\tau\left(\frac{dz}{ds}\frac{d^2y}{ds^2}-\frac{dy}{ds}\frac{d^2z}{ds^2}\right)ds=0, \text{ \&c.}$$

Transposing, squaring, and adding, and putting ρ for the radius of curvature, we obtain

$$C^2R^2 \sin^2 i = \tau^2 : \rho^2, \text{ or } \rho = \tau : CR \sin i,$$

which is constant. The curve is therefore a helix. Also the radius of curvature of the projection of the curve on a plane perpendicular to the axis will be $\rho \sin^2 i$, viz. $= \tau \sin i : CR$.

"The value of τ depends doubtless on the nature and pressure of the gas, and perhaps also on the current; but it must be the same for equal values of C of opposite signs. Hence the handedness of the helix will be reversed by reversing either the current or the magnetic polarity. If the left-hand magnetic pole be north (*i. e.* austral, or north-pointing), and the left-hand terminal positive, the helix will be right-handed."

The general nature of the phenomenon may therefore now be described as follows:—"First, we have the bright spark of no sensible duration which strikes nearly in a straight line between the terminals. This opens a path for a continuous discharge, which being nearly in a condition of equilibrium, though an unstable one, remains a short time without much change of place. Then it moves rapidly to its position of equilibrium, the surface which is its locus forming the sheet. Then it remains in its position of equilibrium during the greater part of the discharge, approaching the axis again as the discharge falls, so that its equilibrium position is not so far from the axis. Thus we see two bright curves corresponding to the two positions of approximate rest united by a less bright sheet, the first curve being nearly a straight line, and the second nearly a helix traced on a cylinder of which the former line is a generating line.

"It was noticed that the sheet projected a little beyond the helix. This may be explained by considering that at first the discharge is more powerful than can be maintained, so that the curve reaches a little beyond the distance that can be maintained."

The appearance of the discharge when viewed in a revolving mirror (except the projection beyond the sheet, the illumination of which was too feeble to be observed) confirmed the above remarks.

II. "The Residual Charge of the Leyden Jar." By J. Hopkinson, M.A., D.Sc. Communicated by Prof. Sir William Thomson, F.R.S.

(Abstract.)

1. If it be assumed that a dielectric under electric induction has every element of volume of its substance in an electropolar state, and also that dielectrics have a property analogous to coercive force in magnetism whereby time is requisite for the development or decay of this electropolar state, an explanation of the residual charge of the Leyden jar